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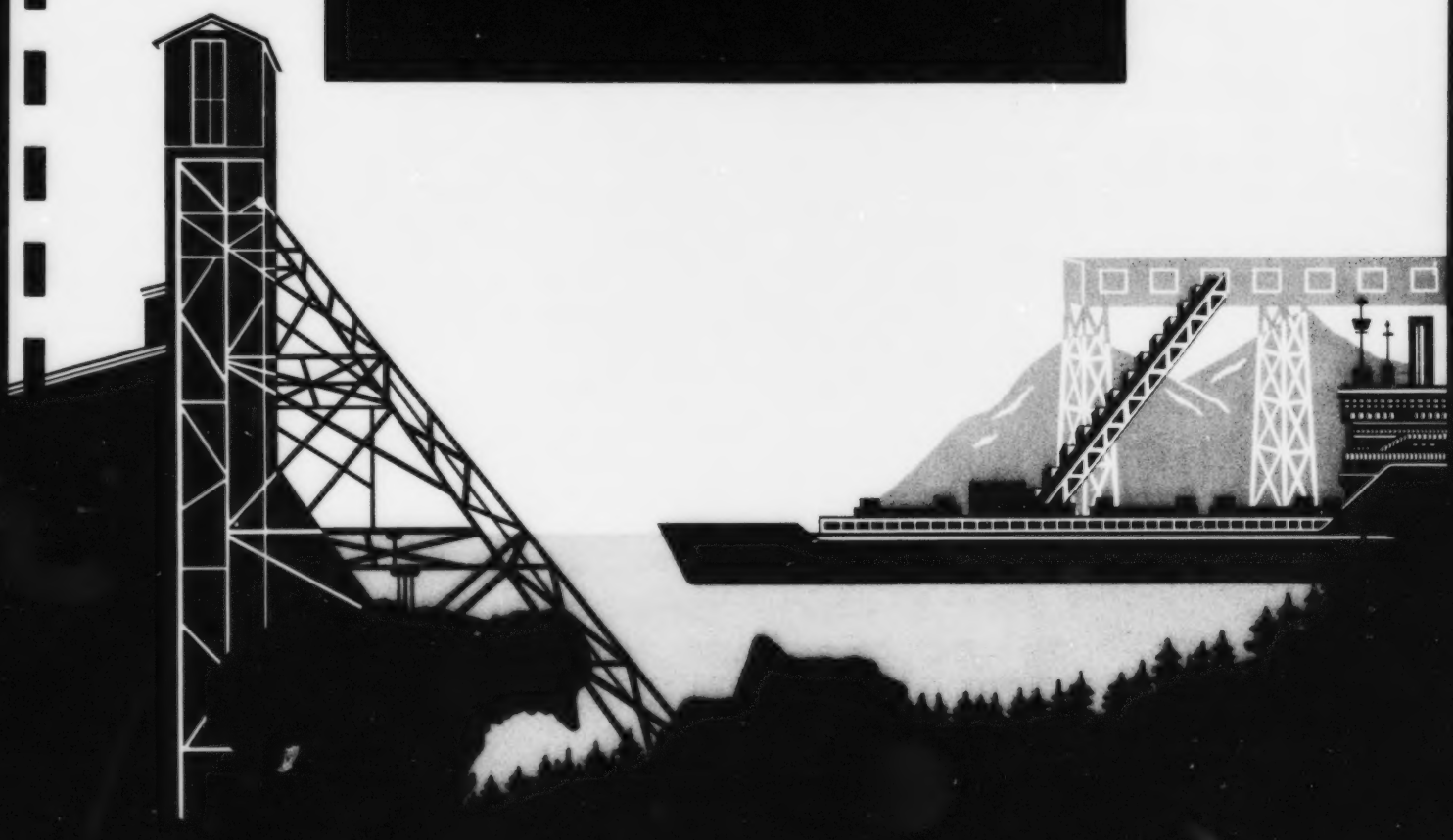

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This report is one of many initiated by the program subcommittees of the Canada - Nova Scotia Mineral Development Agreement. The work represented here by this report and other projects fulfills the Agreement's mandate to promote and strengthen the mineral industry of Nova Scotia.

Canada - Nova Scotia
Mineral Development Agreement

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AN ASSESSMENT OF THE HYDROCARBON AND COMPRESSED AIR STORAGE POTENTIAL OF NOVA SCOTIA SALT DEPOSITS

A SUMMARY

BY

Nolan, Davis & Associates (N.S.) Limited
Halifax, Nova Scotia

FOR

Mineral Policy Sector
Energy, Mines and Resources Canada

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INTRODUCTION

Nova Scotia contains abundant deposits of salt (also known as halite). As shown on Figure 1, salt-bearing geological formations occur almost exclusively within the Windsor Group of bedrock strata in the northern part of mainland Nova Scotia and Southern Cape Breton Island. Although two salt deposits (in Pugwash and Nappan) are currently being mined, there are more than sufficient salt resources in the province to meet the anticipated demand for thousands of years to come and still allow for alternative uses of some Nova Scotia salt deposits. One of these potential uses which, on a world-wide scale, has increased in significance in recent years, is the development of caverns in salt deposits for use as underground storage facilities.

The potential for Nova Scotia to become a producer and distributor of energy is increasing - with planned and possible future development of large scale regional projects such as the Hibernia Oil Field, the Venture Gas Field and the Fundy Tidal Power Development. An important factor in the establishment of Nova Scotia in the energy sector, is the development of reliability and stability of supply. Suitable large capacity storage facilities are required to meet this need, both for hydrocarbon (oil and gas) storage and for the utilization of tidal power on a large scale in conjunction with a Compressed Air Energy Storage (CAES) facility. A CAES facility, in which air that has been compressed by the harnessing of tidal power is stored is usually operated in conjunction with a thermal power plant to re-time the cyclic nature of tidal power and reduce the amount of fuel used for power generation.

Salt has a number of physical properties which make it ideal for the development of underground storage facilities. It has a very low permeability, which means that certain fluids may be efficiently retained within the storage facility. In addition, salt is highly soluble in water, which allows for relatively inexpensive development of storage caverns in salt deposits by dissolving the salt using equipment and personnel on the surface. As a result, the storage of large volumes of hydrocarbons in salt caverns is significantly less costly than in above-ground tank farms, as well as being environmentally safer and aesthetically more appealing.

The Department of Mines and Energy of the Province of Nova Scotia has identified the linkage between the energy and geologic sectors in the area of storage in salt. The Canada - Nova Scotia Mineral Development Agreement (1984) targeted this area for study. As part of this process, Nolan, Davis & Associates Limited were retained to study the potential for using Nova Scotia's abundant salt deposits as energy-related storage sites. Nolan, Davis in turn retained the specialist services of PB-KBB Inc. of Houston, Texas, a company that has been involved in the design and operation of salt cavern storage facilities in the United States and elsewhere. The specific energy-related products of interest were identified as crude oil, liquified petroleum gases (LPG), natural gas, and compressed air.

HISTORY OF UNDERGROUND STORAGE

The technology for development of storage caverns in salt deposits is well-established. On a world-wide basis, storage caverns that are currently in use efficiently contain a wide variety of commodities and materials ranging from petroleum products to bulk foodstuffs, compressed gases and hazardous wastes. Prior to and during World War II, Germany developed a number of salt caverns to stockpile petroleum. In the 1970's, the United States established the Strategic Petroleum Reserve (SPR) Program in response to the threat of disruption of imported oil supplies. The objective of the SPR was to develop storage capabilities of 160 million cubic metres (1 billion barrels). Underground salt caverns have been widely exploited to meet this objective. An intensive, but brief, evaluation of the potential for applying this technique to Nova Scotia salt deposits was carried out in the late 1970's as part of the United States SPR Program. Interest subsequently waned, however, due to the changing political and economic climate.

In Canada, both the petroleum producing and consuming sectors each use naturally occurring and artificial underground reservoirs to stabilize supply and demand requirements. Currently, underground storage capacity in Ontario is 3.5 billion cubic metres of natural gas (in both

porous carbonate and salt deposits). LPG and natural gas have been stored in salt caverns in the Prairie Provinces and southwestern Ontario for the past 25 years. Similar experience has been gained in Europe, Japan and the United States. It is evident that subsurface storage has attained considerable importance relative to surface storage systems in recent years.

GEOLOGY OF SALT IN NOVA SCOTIA

Salt, gypsum, potash and anhydrite are "evaporite" deposits which were formed in shallow enclosed seas in a hot, dry climate at some point in geologic history. These deposits are the precipitated salts of sea water under evaporative conditions. Evaporite deposits are widespread in central, northern and eastern Nova Scotia and belong to the Windsor Group of sediments of the Lower Carboniferous Period. Figure 1 shows the distribution of Windsor Group bedrock and the various known salt deposits, grouped into nine geographical areas. Five of these nine areas have known salt occurrences; namely, Hants-Colchester, Cumberland, Antigonish-Mabou, Canso-Bras d'Or, and Sydney areas.

Certain criteria must be met to establish a safe, efficient, underground storage facility. This requires an orderly approach to the study of various known salt deposits. Initially, it is helpful to arrange the geologic information from each deposit into large-scale characteristics, then consider relevant economic and technical factors. This process is followed by a more detailed evaluation of potentially suitable sites, through collection and assessment of site specific geologic data (Table 1).

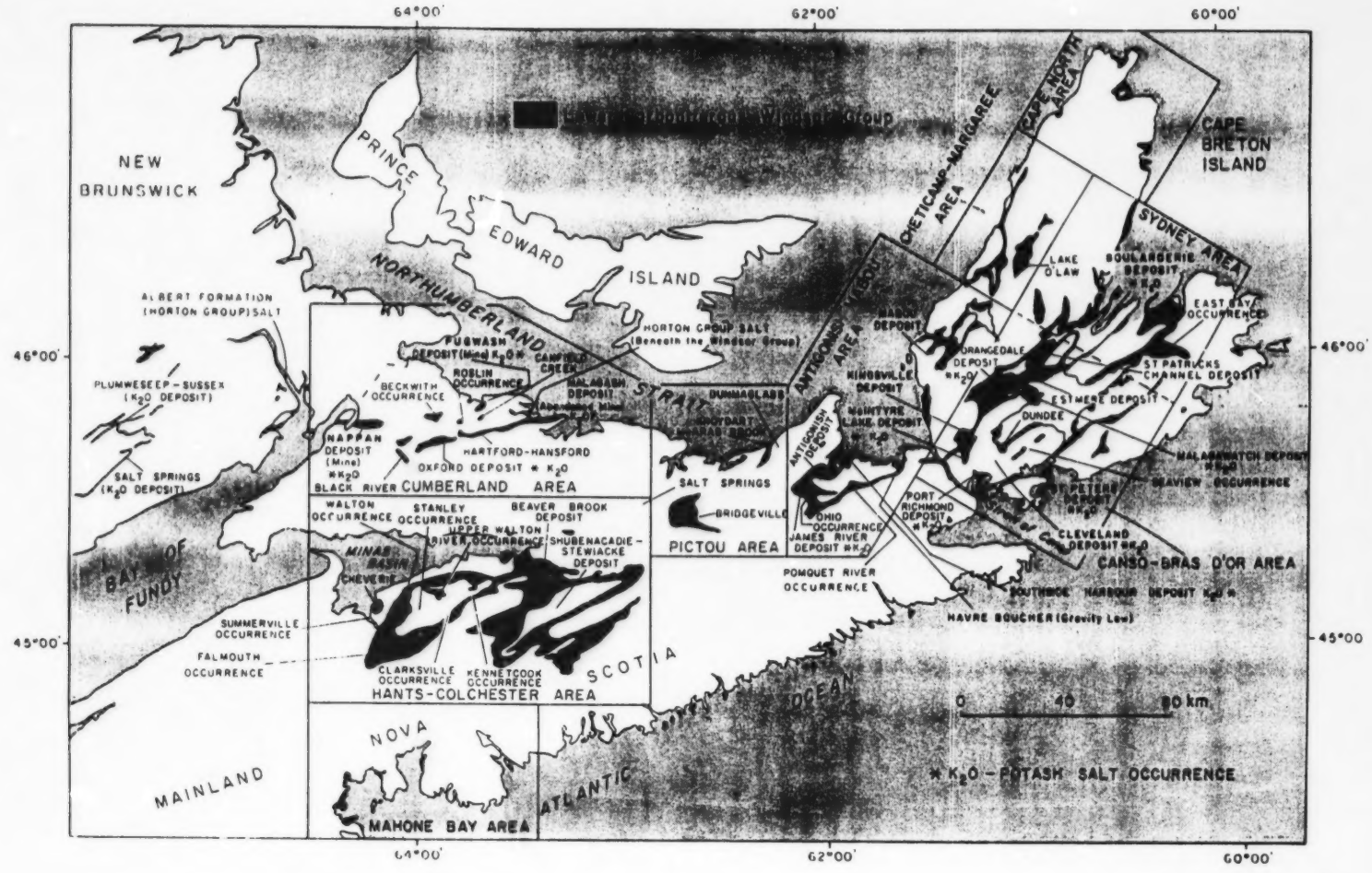

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FIGURE 1
WINDSOR GROUP OUTCROP
DISTRIBUTION AND SALT OCCURENCES
IN NOVA SCOTIA

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TABLE 1

Geological Parameters Required for Detailed Cavern Feasibility Study

1. **Megascopic Geological Features**

   - Salt Depth
   - Salt Thickness
   - Utilization History

2. **Structural Geological Features**

   - Folding
   - Faulting
   - Brecciated Zones
   - Nature of Caprock/Salt Interface
   - Seismic Activity
   - Surface Subsidence

3. **Stratigraphy**

   - Thickness of Enclosing (overlying) Strata
   - Discontinuities within Enclosing Strata
   - Insoluble Material Content of Salt
   - Highly Soluble Mineral Content (e.g. Potash)

4. **Hydrogeology**

   - Dissolution Features (e.g. Karst Topography)
   - Salt Springs at Surface
   - Porosity Data
   - Permeability Data
   - Deleterious Fluids (Groundwater, Brine, Gas Pockets)

5. **Geophysics**

   - Detailed Gravity Survey
   - High Resolution Seismics
   - Downhole Geophysical Data

6. **Physical and Rock Mechanics Parameters**

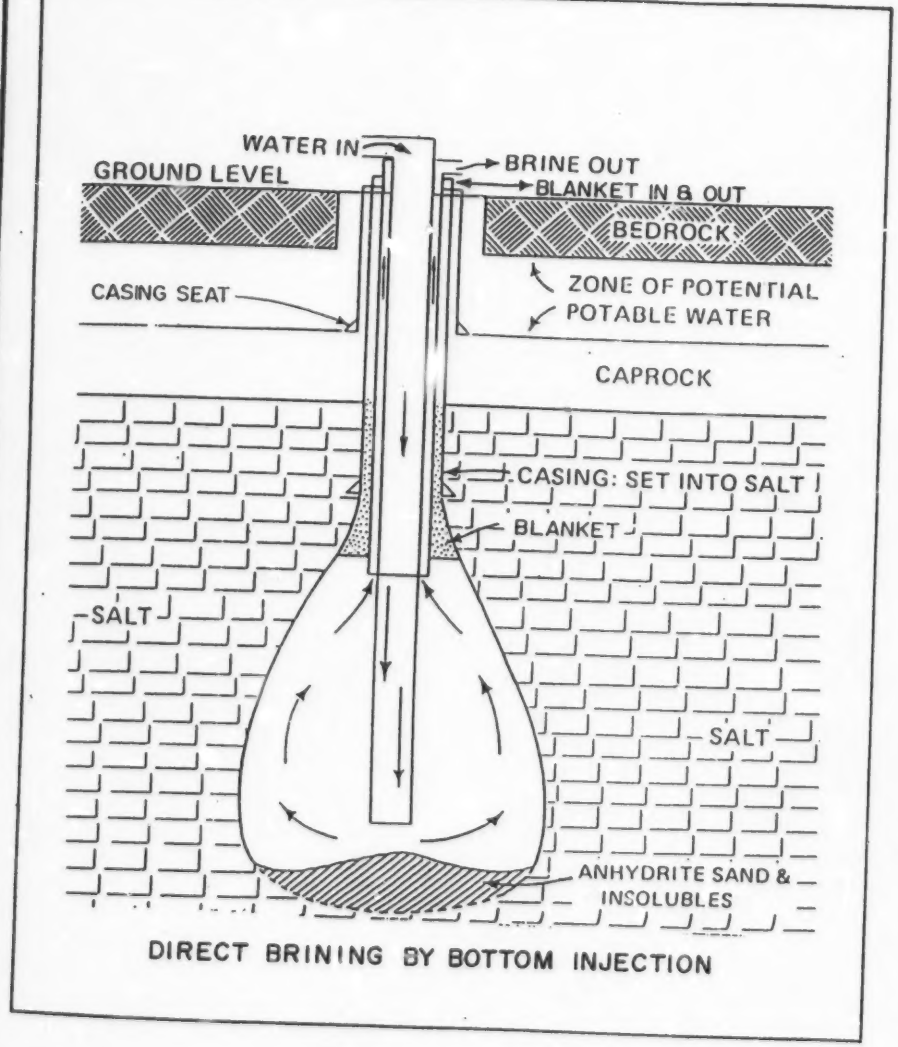
   - Geochemistry
   - Temperature
   - Moisture Content
   - Tensile Strength
   - Compressive Strength
   - Thermal Conductivity
   - Thermal Diffusivity

CAVERN DEVELOPMENT AND OPERATION

Salt deposits can make convenient storage containers. This is largely due to the economy of the cavern development technique known as solution mining. This involves the penetration of the deposit using standard oil well drilling practices with fresh water being introduced to the deposit creating a brine (water containing dissolved salt) which is subsequently returned to surface. The future cavern is connected to the surface by pipe cemented inside the drill hole. Inside this cemented pipe, two concentrically arranged suspended pipe strings act as conduits for injection of water and withdrawal of brine. Altering the direction of flow (inward or outward) in each of the conduits and varying the depths of the suspended strings helps control cavern shape (see Figure 2). Upward growth of the cavern is restrained by injection of a liquid that is lighter than water (eg. oil) which floats on top of the water/brine and "blankets" the cavern roof. Geophysical devices suspended on wirelines, and the study of the returning water, together with computer simulation, help the engineers and geologists monitor cavern growth.

Depending on the substance stored, various cavern operational techniques are used. Low pressure liquids such as crude oil or LPG can be displaced by water or brine, if further cavern enlargement is to be controlled. Alternatively, submersible pumps can be installed. This technique allows for very high withdrawal rates, but it becomes more expensive and less desirable as depth increases. If pressurized gases such as natural gas or compressed air are to be stored, the cavern acts as a pressure vessel connected to delivery lines on the surface.

Many of the criteria for salt cavern storage are common to all types of storage. One of the factors which differs is the storage depth, which is dependent upon pressure requirements. Figure 3 illustrates the most desirable depth intervals for developing caverns for the storage of crude oil, LPG, natural gas, compressed air, and hazardous waste. The greatest possible depth interval to be considered for any storage development project is from 300 to 1,800 metres (1,000 to 6,000 feet).



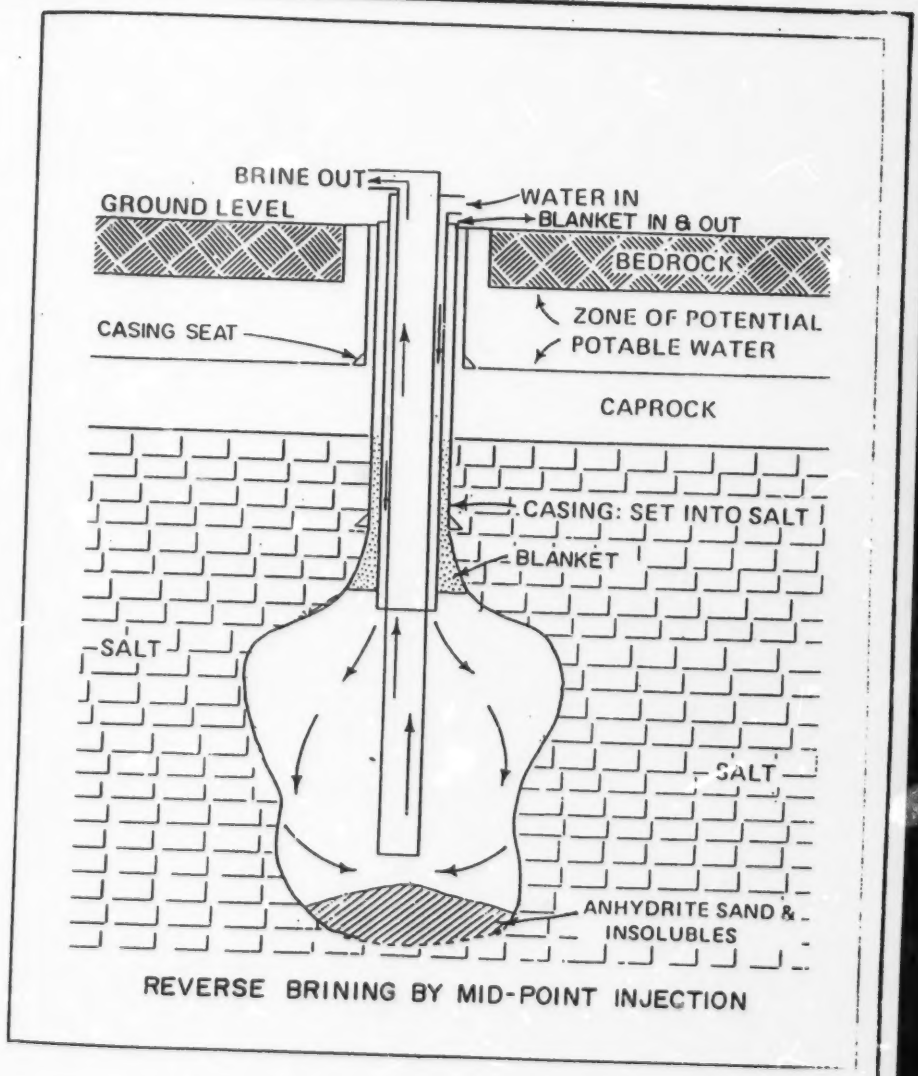


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FIGURE 2

CONTROL OF CAVERN SHAPE DURING SOLUTION MINING

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TYPES OF SALT CAVERN STORAGE

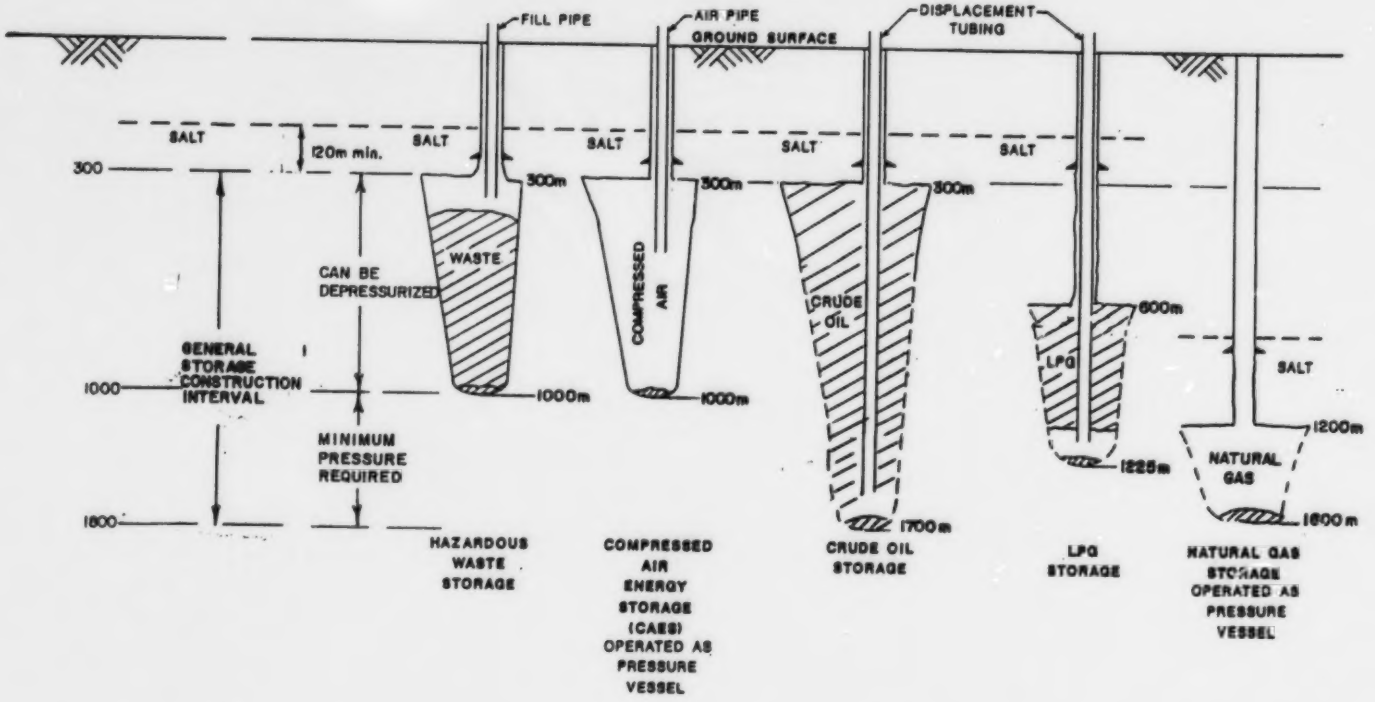

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FIGURE 3

OPTIMAL DEPTHS FOR VARIOUS CAVERN STORAGE SUBSTANCES

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GEOTECHNICAL CONSIDERATIONS AND CAVERN DESIGN

In addition to those mentioned in the introduction, other features of salt are amenable to its storage capabilities. Over a geological time scale, salt is very flexible and flows or molds easily. With relatively small differences in pressure on a deposit, the salt will migrate slowly from a region of higher to lower pressure (this, along with its relatively low specific gravity, has resulted in the common occurrence of salt in arched domes or diapirs, created by upward movement of salt under pressure). This indicates salt's non-brittle or plastic behavior- its ability to flow to redistribute stresses, rather than cracking or fracturing. The plasticity of salt, together with its very low permeability, promotes self-sealing as the salt invades porous zones and fractures in the over-lying rock strata.

Cavern siting and design requires accurate definition of the geologic structure and properties of the salt deposit. For regularly bedded and domed deposits, the salt thickness and purity can often be assessed fairly accurately based on limited data. In highly deformed or depositionally complex deposits, more detailed drilling programs and geophysical surveys may have to be part of the general assessment, and certainly are required for final siting or cavern design.

Inhomogeneities within the deposit caused by the presence, for example, of insoluble layers (anhydrite, mudstone, limestone, etc.) or weak zones may result in cavern flaws or construction problems. Certain structural complexities (such as high angle vertical folds) may demand precise placement of the cavern.

The nature of the enveloping and overlying layers must be understood. Those layers must be able to support the overburden and provide a stable vessel to contain the stored substance. Seismic stability of the rock mass must also be considered in site selection. Earthquake activity in Nova Scotia is minor compared to other parts of Canada, and cavern design can take into account the expected ground motions (shock waves) so that damage from low level seismic events would not occur.

The behaviour of salt rock depends strongly on the moisture content, temperature, and the pressure the deposit is subjected to. Relatively small increases in any of these parameters increases its mobility - resulting in possible long-term cavern closure.

The design of salt cavern storage facilities must abide by constraints set by large and small scale geological factors, with regard to safety and economy in all phases of construction and operation. Design must be, therefore, specific as to site and purpose. The primary goal of cavern design is to maximize storage volume per surface area, while maintaining structural stability and pressure tightness. This is accomplished by optimizing cavern size, height and arrangement of several caverns with a particular deposit.

Sufficient salt must be left in place to accommodate the demands of stress on the rock "walls" surrounding the cavern. During operation, the pressure within the cavern must be maintained so as to minimize the effects of differential stress between cavern and deposit which could result in salt "creep" and cavern closure, or fracture and collapse if the stresses in the surrounding rock exceeds its strength. It is most desirable to maximize cavern height to preserve an ample surrounding salt envelope while creating maximum volume per unit surface area of a deposit. This also simplifies the solution mining process.

Cavern height, however, is limited by the density or unit weight of the material to be stored. If a substance has a unit weight much different from the "effective" unit weight of the overlying deposits, the result is differential stresses in the cavern walls. The difference between the static pressure generated by the overburden and the lower pressure produced by the self weight of the stored material will exceed the rock strength at depth. A cavern 600 m in height, placed within the depth range 300 m to 1700 m, is usually the maximum practical for oil storage caverns. If operations require complete cavern evacuation/depressurization then the maximum depth limit is reduced to about 1000 meters.

Cavern shape and spacing can be used to manage deposit integrity and volume requirements. Generally, the diameters of caverns must be less than their heights, while pillar width (minimum distance between adjacent

caverns) to cavern diameter ratios and salt roof thickness to diameter ratios of at least 2 are required. An arch shaped roof provides the best redistribution of stress.

Optimizing cavern size is strongly dependent on site and operational criteria. Experience has shown that 950,000 cubic meters (6 million barrels) is a workable target for cavern volume. The effects of cavern growth due to product cycling and shrinkage, due to salt creep and build-up of insoluble material on the floor during the solution process, must be accounted for.

Determining optimum well size and number per deposit primarily depends on operational requirements. Design of drilling and casing programs, including selection of hole, casing sizes and depths have to accommodate required flow rates as part of the solution mining process and product movement while assuring groundwater quality and facility integrity.

The cavern design process requires experience and experiment along with detailed field assessment and computer simulation prior to and during the construction process. Proper preparation prior to the commencement of solution mining and cavern development will minimize potential difficulties in the later stages of cavern development and product storage.

ENVIRONMENTAL CONSIDERATIONS

Environmental impacts that must be considered in the development of salt cavern storage facilities relate to all aspects of construction and operation, including the disposal of any potentially harmful material. Heavy construction activity (for roads, buildings, retaining ponds, and pipelines for stored substance cycling, water supply and brine disposal) may pollute surface and groundwater resources, disrupt wildlife habitats and/or promote soil erosion. Docking facilities, if needed, may create marine based environmental problems during construction and operation - including spills in the dock area or by tankers in transit. If rivers or lakes are used as the water supply source, the effects on their ecosystems must be studied, and if wells are used, proper groundwater management

policies must be adhered to. All installations, including storage caverns, holding ponds for drilling fluid, and blanket material storage facilities, have to be properly engineered to minimize the possibility of leaks or spills.

The most difficult problem in design, from the environmental and sometimes the economic standpoint, is brine disposal. This is primarily due to the very large volumes involved. The problem arises during the cavern construction stage and sometimes during product cycling operations. Brine can be disposed of in the ocean, or alternatively, it can be injected into deep wells. With the ocean brine disposal method, brine is pumped from the cavern into pipelines and then into the ocean through a diffusion tube; a pipe with holes placed several meters apart, to distribute the saline effluent. This affects the marine environment by increasing salinity in the vicinity of the diffuser pipe, the magnitude of which depends on local circulation and mixing of the receiving water. This can create an environment unfavourable to some marine life, especially to less mobile forms. Trace elements found in salt deposits may also be harmful to the oceanic ecosystem if present in the brine in elevated amounts.

Deep well injection of brine is a proven method widely used in the United States. Its major advantages are that the brine is not discharged to surface waters, it is more economical than treatment, and little land is used. The greatest disadvantage is the potential contamination of fresh water aquifers (which, therefore, must be accurately delineated and protected from brine intrusion).

Other options for brine disposal involve utilization of the salt as a resource, including extraction of the salt for commercial sale, use as the raw material in chlorine production, and use as a feedstock for a petrochemical industry. The selection of a particular site and other economic factors will determine the feasibility of using these methods.

SITE SELECTION

Twenty-seven known salt deposits and occurrences in five geographical areas of Nova Scotia were initially examined as potential

storage cavern sites. The variable source and level of detail of relevant data (ie. geophysical surveys, boreholes, etc.) on deposit each necessitated an initial broad-scoped feasibility evaluation. All readily available geological, geophysical, engineering, environmental and logistical data were collected on each and the following factors were used in selecting the most promising sites for salt cavern development:

- Sufficient thickness and extent of salt section
- Salt relatively free of impurities
- Sufficient thickness and type of overlying rock
- Availability of water for solution mining
- Disposal site or secondary use for waste brine
- Proximity to supply/market

Based on these criteria, seven sites were chosen as presently showing the most promise (Figure 4). These are:

TABLE 2

Most Suitable Salt Deposits
For Development of Storage Caverns

GEOGRAPHICAL AREA	DEPOSIT	RANK*
Hants - Colchester	Shubenacadie - Stewiacke	2
	Beaver Brook	6
Cumberland	Nappan	5
Canso-Bras D'Or	McIntyre Lake	3
	Port Richmond	1
	Kingsville	4
Sydney Area	Boularderie	7

* Sites are ranked from 1 to 7 with the lowest number indicating the most favourable, based on technical, geological economical and logistical factors.

The site selection data for these sites are summarized on Table 3. The data from these sites were then studied in more detail and the

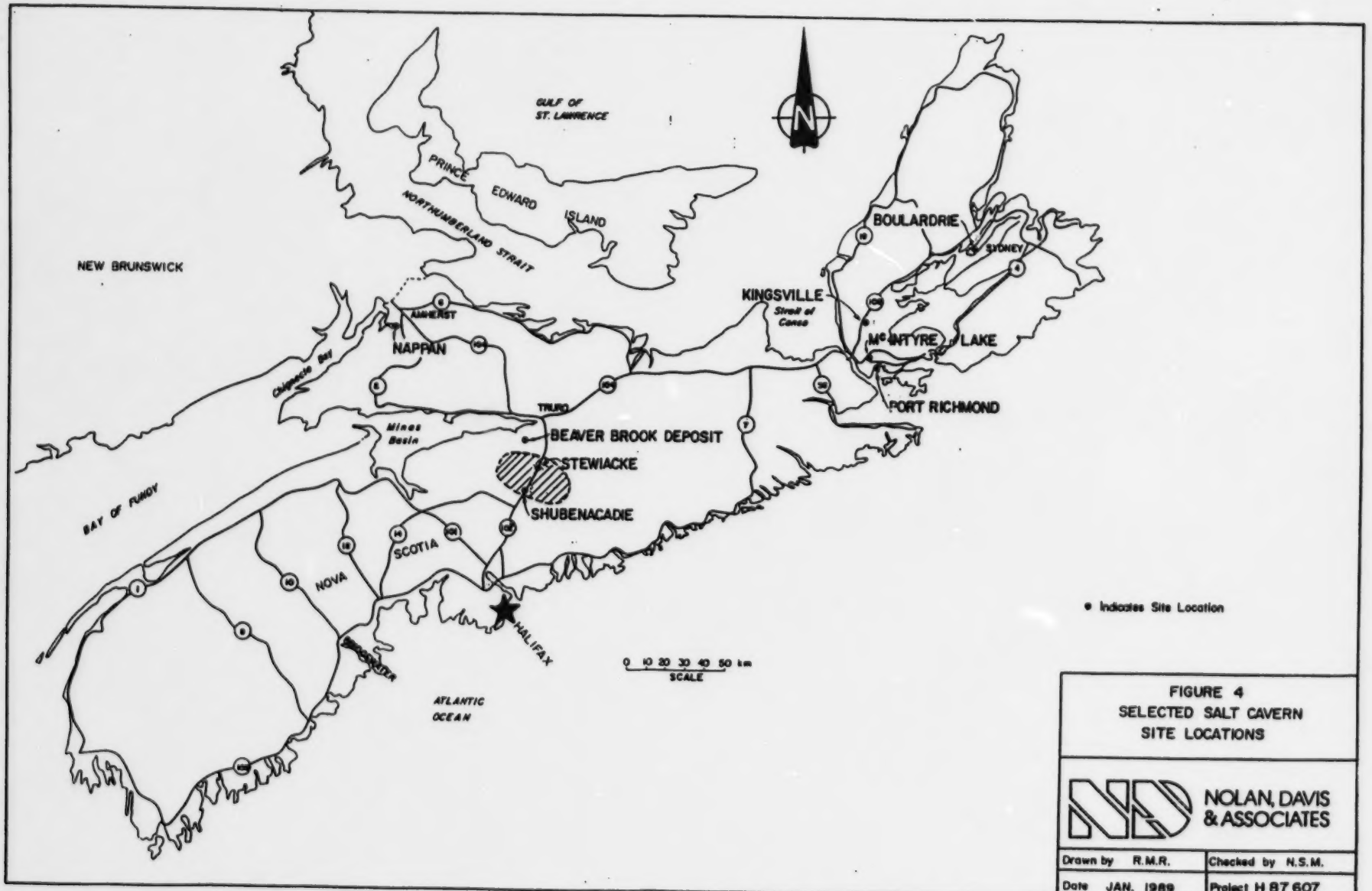

FIGURE 4
SELECTED SALT CAVERN
SITE LOCATIONS

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Drawn by R.M.R.	Checked by N.S.M.
Date JAN. 1989	Project H 87 607

TABLE 3

SITE SELECTION DATA SUMMARY

	SITES						
	Port Richmond	McIntyre Lake	Kingsville	Beaver Brook	Nappan	Shubenacadie -Stewiacke	Boularderie
Extent & Thickness	4 km diameter 255 – 1050 m	7 x 10 km 574 m	1 x 10 km 540 m	1 x 5 km 300 – 450 m	4 km diameter 1,300 m	40 x 15 km 300 m	? 335 m
Salt Purity	85%	85%	90%	90%	97%	87%	90 – 95%
Cap Rock	250 – 550 m Shale Quartzite Conglomerate Anhydrite Limestone	255 m Siltstone Gypsum Shale Sandstone Limestone Anhydrite	400 m Siltstone Gypsum Sandstone Conglomerate Mudstone Shale Halite Limestone Dolostone	360 m Shale Siltstone Dolostone Anhydrite Limestone	310 m Shale Gypsum Sandstone Limestone Anhydrite	400 – 500 m Siltstone Gypsum Sandstone Conglomerate Limestone Anhydrite	495 m Sandstone Siltstone Mudstone Limestone Dolostone Anhydrite Gypsum
Water Source	Strait of Canso	Strait of Canso	Strait of Canso	Shubenacadie River	Nappan River	Shubenacadie/ Stewiacke River	Bras d'Or Lake
Brine Disposal	Strait of Canso	Strait of Canso	Strait of Canso	Shubenacadie River	Nappan River	Deep-Well Injection	Bras d'Or Lake
Potential Market	International	International	International	New England	New England	New England, Halifax	Sydney
Suitable Substances	Crude Oil, LPG, Natural Gas	Crude Oil, LPG	Crude Oil, LPG, Natural Gas	CAES	CAES	Crude Oil, LPG, Natural Gas	Crude Oil, LPG, Natural Gas

seven sites were ranked in order of greatest promise for further development. Further information on each of these sites is provided in Appendix A, in order of their rank.

ECONOMICS

From the foregoing, it is evident that Nova Scotia salt deposits have significant salt cavern storage capabilities. Installation of petroleum storage systems in conjunction with offshore energy projects such as the Venture gas field would markedly improve Atlantic Canada's economic outlook by providing a cheap, clean, reliable, indigenous fuel supply. The local market, however, is currently not large enough to support such a project. The implementation of the Free Trade Agreement with the United States is likely to better Nova Scotia's competitive standing with New England and encourage the development of a local industrial base which has ready access to Venture gas, in addition to increasing export demands for the gas itself in this competitive market. Surge storage to accommodate seasonal demand cycles is a normal component of a natural gas transmission system and it is logical to consider Nova Scotia salt deposits for this purpose.

The other major potential function for Nova Scotia salt cavern usage is a strategic oil reserve (low containment pressure requirements for crude oil storage and little need for crude oil surge storage make commercial use of salt caverns uncommon). The Strait of Canso area offers a near-perfect location for a regional strategic reserve to serve New England and the Canadian east coast. Both regions rely heavily on tanker traffic to import oil. The Port Richmond deposit has an estimated capacity of 300 million cubic meters in addition to the larger adjacent Lake McIntyre deposit. Abundant water supply, convenient brine disposal and proximity to deep water ports to serve New England and eastern Canada make this area very attractive. The Shubenacadie-Stewiacke deposit also has an estimated capacity of 300 million cubic meters in a less complex and better

defined setting. However, its inland position makes it less desirable for a strategic reserve that is serviced by tanker shipping.

In addition to the American SPR Program, some Middle Eastern OPEC nations have expressed interest in developing an oil bank to secure income in troubled times. Thus, there are strong arguments for using Nova Scotia salt deposits for a strategic oil reserve, using oil from the east coast offshore, the Middle East or elsewhere. The Nova Scotia reserves would provide a large, centrally located supply in a politically stable region. Given the current economic and energy supply climate, large scale storage of crude and refined petroleum is economically feasible.

LPG (eg. propane) offers another opportunity for storage. Atlantic Canada's use is small and its future depends, in part, on offshore (Venture) development. A cheap, indigenous supply may increase local demand. The Free Trade Agreement may open markets in New England and LPG can be a competitive alternative fuel in rural areas or regions not served by a natural gas pipeline.

Compressed air energy storage (CAES) is a technology for storing excess energy in the form of compressed air in underground reservoirs for use in generating peak load electricity. Using compressed air, the energy of the fuel consumed in the combustion turbine of a CAES facility is devoted almost entirely to generating electricity. To produce a given amount of electricity, therefore, a CAES power plant consumes substantially less fossil fuel. Petroleum and tidal power as energy sources for the compression of air are deemed economical on the large scale.

Due to the cyclic nature of tidal power generation CAES is highly compatible with this method. However, large scale development is not probable in the near future, since it is not yet technically or economically feasible. As well, with the current trend in Nova Scotia of developing coal fired generating stations and the possibility of future plentiful and economic natural gas supplies, CAES is not attractive as a fuel saving technique at present.

It is estimated that current (1988) salt storage development costs will range from $17 to $25 per cubic metre ($2 to $3 US per barrel). This cost per unit volume is independent of the size of the reserve being

considered. It is dependent on the average volume of each individual cavern; larger caverns are more economical per unit volume to develop.

SUMMARY AND CONCLUSIONS

Underground storage offers an attractive alternative to surface storage. Studies carried out for the United States SPR Program comparing surface and underground storage methods concluded that the least environmental impact was associated with underground storage in salt caverns. In general terms, the following advantages also apply:

- economical, in terms of both investment and maintenance
- structural stability
- storage is fireproof and protected from extensive damage caused by internal explosion
- large volumes can be stored and expansion can be undertaken economically
- mined mineral produced can be a valuable by-product
- efficient use of land
- aesthetically appealing, causes the least amount of interference with the surface environment.

The present study has indicated the feasibility of developing salt caverns in Nova Scotia for large scale energy-related storage purposes. Nova Scotia is logistically well situated for future energy production from the offshore and Fundy Tidal Power and strategically located for distribution purposes with its proximity to the New England market. This makes the salt deposits of Nova Scotia a valuable asset.

The dimensions of the Port Richmond deposit make it suitable for storage of all substances considered. Problems exist, however, in defining its complex character with respect to structure and the presence of insoluble layers. Close proximity to the Strait of Canso make this the best site for crude oil and liquid petroleum gas storage.

The large and geologically simple Shubenacadie-Stewiacke salt deposit is nearly ideal for cavern development. However, its inland position makes development and product cycling uneconomical at present.

The large McIntyre Lake deposit 16 kilometers from the deep water port of the Strait of Canso has good potential for crude oil and liquified petroleum gas storage. The proximity of the Kingsville site to the Strait of Canso also favours it for storage of crude oil and LPG, but it requires construction of a 32 kilometer pipeline.

The depth, relative purity, and thickness of the Nappan and Beaver Brook deposits are conducive to cavern development. Their location near the Bay of Fundy make compressed air storage in conjunction with Fundy Tidal Power, a possibility for the future.

All substances considered in the study (crude oil, natural gas, LPG and compressed air), are capable of being stored in the Boularderie deposit (70 kilometers by land from Sydney). Proposed deepening of the Bras D'Or channel to the Atlantic Ocean (to allow larger vessels to pass) may make this site economically attractive in the future.

Present economic and technical factors indicate that the best opportunities for salt cavern utilization in Nova Scotia are related to future development of the Venture Gas Field or for strategic oil reserve purposes.

The geological information available on each of the salt deposits in this study is variable in its source and level of detail. Further detailed work is needed to delineate the complexity of some of the most promising sites as a prelude to assessing storage opportunities and carrying out preliminary design with respect to specific project requirements.

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APPENDIX A

Summary of Geologic Data from Seven most Promising Deposits

SUMMARY OF GEOLOGICAL DATA FROM SEVEN MOST PROMISING DEPOSITS

Rank and Deposit	Description
1 Port Richmond (Canso - Bras D'Or Area)	The physical dimensions of this salt deposit present a wide range of storage opportunities. Based on borehole data and geophysical information the deposit has been delineated as a mass about 2.5 km in diameter and more than 1500 m deep at its centre. The depth to the top of the salt ranges from 250 to 500 metres below ground surface with the bottom of the salt extending from 600 to 1500 meters. The useful portion of the deposit can be considered a cylinder 2.5 km in diameter and about 1000 meters in depth. Assuming cylindrical caverns 600 m tall and a salt pillar/cavern ratio of 2:1, the maximum storage capability is 2.9 million cubic meters. It would seem this deposit would be appropriate for storage of all substances considered. Water for solution mining is available in nearby Inhabitants Bay while offshore brine disposal is possible. A main advantage is proximity to the Strait of Canso and the Gulf Oil Refinery. Disadvantages include the complex structures and stratigraphy and possible predominance of insoluble layers.
2 Shubenacadie - Stewiacke	The Shubenacadie - Stewiacke salt deposit would provide an excellent site for underground storage of crude oil, LPG, and natural gas. Lack of water for solution mining and brine disposal difficulties are the major limitations. Water could be obtained from the Shubenacadie or Stewiacke Rivers and the brine could be injected into deep wells. However, during low-flow periods it may be difficult to obtain sufficient water from these rivers. Another alternative is to obtain solution mining water from the Minas Basin 30 to 40 kilometers northwest. Brine could be pumped to the Minas Basin for disposal or it could be used for the

production of salt or chlorine. The high cost of pipeline construction and the lack of markets for salt may make these options unsuitable. In addition, the inland setting of this deposit does not favour economical product cycling.

3 McIntyre Lake

A test hole indicates a substantial thickness of salt within the depth interval 260 to 670 meters. The salt deposit is apparently large and at a good depth for petroleum storage. However, more detailed exploration is needed before a suitable site can be selected. Available geological data indicates the McIntyre Lake deposit is inferior to the Port Richmond site for development of underground storage facilities. Water for cavern development can be obtained from the Strait of Canso which can also be used in brine disposal. This requires installation of a 16 kilometer pipeline.

4 Kingsville

Twelve holes drilled in the Kingsville area have all intersected significant salt sections. One borehole encountered a 540 meter interval. The area of the Kingsville deposit is about one by three kilometers with proven reserves estimated to be 28.6 million tonnes.

Water for cavern development at this site can come from the Strait of Canso which can also be used for brine disposal. Home Oil and Gulf Canada Limited proposed a 16 kilometer pipeline from McIntyre Lake to the Kingsville site in 1979. Like the McIntyre Lake deposit the Kingsville site is well suited for crude oil and LPG storage because of its proximity to the Strait of Canso.

5 Nappan Deposit

Results from a test hole indicate a salt section 1350 meters thick from a depth of about 425 meters to about 1800 meters. Based on preliminary geophysical data the usable salt reserve appears to have dimensions of at least 4000 by 1300 meters and a conservative total of about 16 billion cubic meters of salt.

The deposit could technically support all kinds of subsurface storage products. Its economic advantage for storage purposes appears to be as a compressed air storage facility in conjunction with a possible tidal power development.

Water for solution mining could be obtained from the mouth of the Nappan River or the Meccan River that discharge into Cumberland Basin. These waters could also serve in brine disposal.

6 Beaver Brook

A single borehole drilled into this deposit intersected good quality salt within the depth interval 630 to 733 meters. The bottom of the salt section is estimated to be at a depth of 1000 to 1100 meters. The apparent dimension of a block surrounding the borehole is 1 by 4 kilometers in area by 300 meters thick with a volume of 1.2 billion cubic meters.

Solution mining water may be obtained from the Shubenacadie River 5 km from the borehole location. The river is brackish at this point so the possibility of using the river for brine disposal exists.

The Beaver Brook salt deposit is much smaller than others considered and limited data are available. Careful exploration and evaluation will be required for site selection and cavern design. A low permeable shale or clay caprock is apparently lacking. The site, however, may be distinctly advantageous for CAES in association with the Bay of Fundy tidal power.

7 Boularderie

The one borehole drilled on this site intersected salt 335 meters thick. Possible development of storage caverns would be simplified by the relatively simple structural and stratigraphic conditions. Bras D'Or or St. Andrew Channel could provide water for solution mining and also offer a location for brine disposal.

The site would be suitable for storage of crude oil, LPG and compressed air for industrial Cape Breton. Proposed deepening of the Bras D'Or Channel to the Atlantic Ocean may give it access to international markets.

Of all the sites considered, several were excluded from further study due to lack of basic requirements, such as insufficient thickness of salt. However, various deposits were eliminated due to insufficient data. Consequently, with the future acquisition of additional, relevant data, the ranking of deposits, as herein reported, could change.